

Air Pollution Sensor Technology- US EPA Activities

Maine Tribes and Maine DEP Air Monitoring Meeting

Augusta, ME
March 26, 2014

Bob Judge
US EPA- New England

“Mention of trade names or commercial products does not constitute endorsement recommendation for use”



Current Air Monitoring



Why



Personal
Exposure and
Health
Monitoring



Near or within Sources
for Regulatory
Compliance



In Communities to Assess
Exposure



In the Ambient Air for
Regulatory
Compliance, to Track
Trends, and for Public
Information



How



Expensive instruments
Specialized training required
Large physical footprint
Large power draw

Convergence of Technologies and Cultural Change

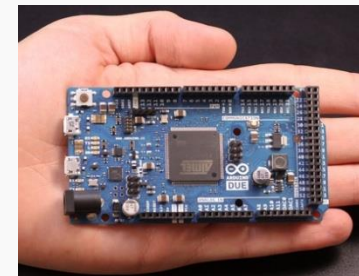


Miniaturized environmental sensors



e.g., CairClip

Introduction of low cost controls and communications



e.g., Arduino microprocessor

Emerging data-viewing/communication apps



AirCasting App

Smartphone / Tablet generation

e.g., fitbit activity tracker



Environmental Science & Technology

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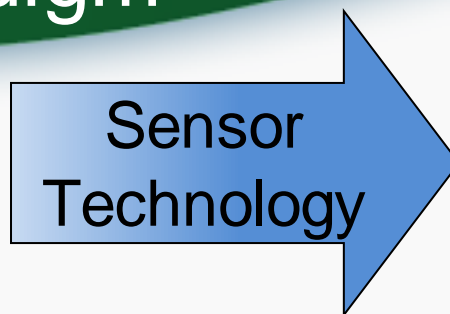
**The Changing Paradigm
of Air Monitoring**



The Changing Paradigm of Air Monitoring

Snyder et al, ES&T, 2013
Accepted

The Role of Sensor Technology in the Changing Paradigm



How data is collected?



Who Collects the data?

Limited Mostly to Governments, Industry, and Researchers

Expanded Use by Communities and Individuals

Why data is collected?

Compliance Monitoring, Enforcement, Trends, Research

New Applications and Enhancement of Existing Applications

How data is accessed?

Government Websites, Permit Records, Research Databases

Increased Data Availability and Access

Next Generation Air Monitoring (NGAM): A Challenge and an Opportunity



- Federal/State/Local governments need to prepare for data deluge and responses to concerned citizens
 - What's the quality of the data?
 - How to interpret data from sensors' short term measurements from a public health perspective?
- Federal/State/Local governments will also have new sources of data to better manage air quality and protect public health
- EPA is engaging with the early adopters and developers of these sensors to help ensure this technology is used in a fashion that is appropriate and most useful to us as regulators and to communities and the public.
- EPA ORD is very active in this area.
EPA- New England is engaged with ORD.



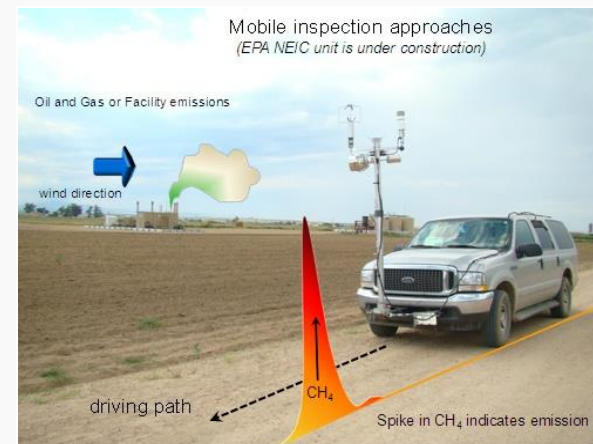
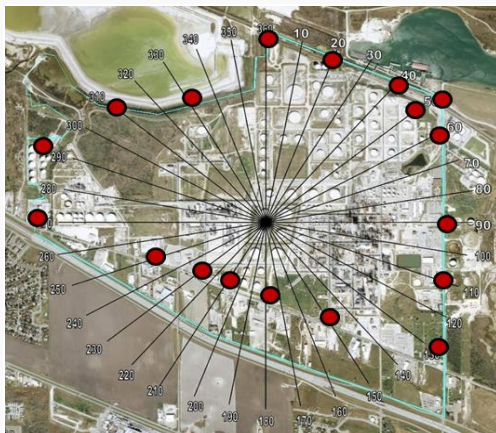
Next Generation Air Monitoring Research at EPA



- Community Monitoring Applications
- Source Monitoring Applications
 - Facility Fence Line and Sensor Networks
 - Geospatial Mapping of Air Pollution (GMAP)
- Evaluating Sensor Technology and Regulatory Considerations
 - Ozone, NO₂, PM, and VOCs



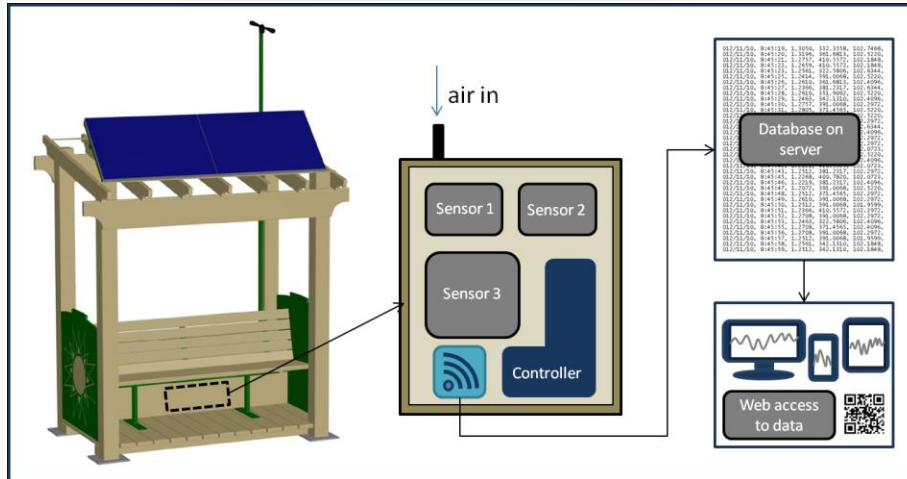
CairClip
(O₃ & NO₂)





Community Monitoring Applications

Village Green Project



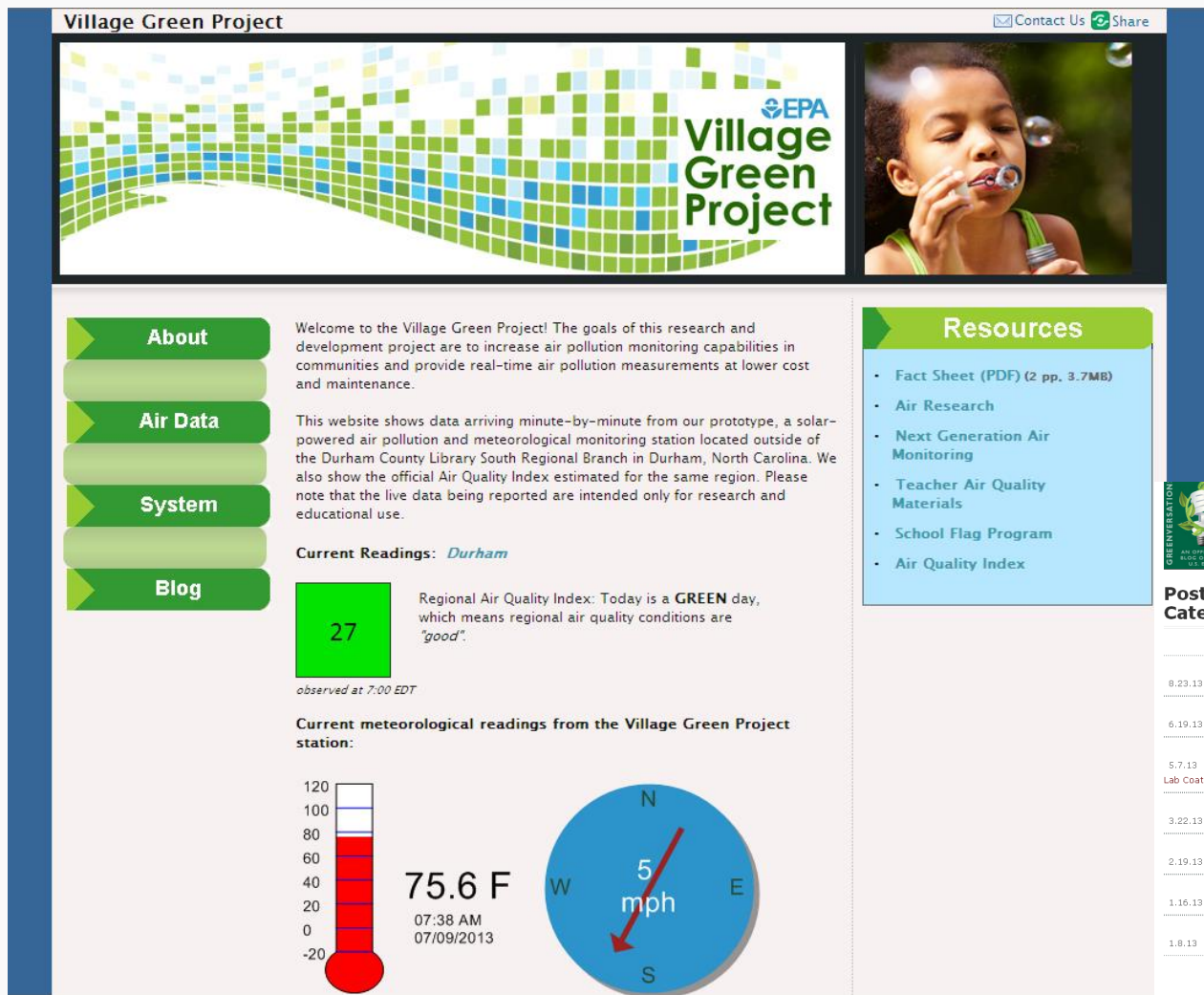
- Self-powered air and meteorological sampler
- Lower cost, real-time instruments - proven capability at ambient levels (wind, black carbon, PM_{2.5}, ozone)
- Wireless data communication to publically-accessible website
- Designed to add value to and be secure in public environments



June 22, 2013 – Opening Day at Durham South Regional Library

villagegreen.epa.gov

Educational and
community outreach
opportunity



Resources

- [Fact Sheet \(PDF\) \(2 pp, 3.7MB\)](#)
- [Air Research](#)
- [Next Generation Air Monitoring](#)
- [Teacher Air Quality Materials](#)
- [School Flag Program](#)
- [Air Quality Index](#)

It All Starts with Science
AN EPA BLOG ABOUT SCIENCE MATTERS

Home About Comment Policy Other Greenversations

Posts from the 'Village Green Project' Category

8.23.13 The Village Green Project: Reading the Results So Far... 0

6.19.13 Come Celebrate, Learn, and—Sit on the Village Green Project! 1

5.7.13 The Village Green Project: An Opportunity for STEM Enrichment (without the Lab Coat) 2

3.22.13 Village Green Project: What's in our Air? 5

2.19.13 The Palm-Sized Wonder that Brings Life to Village Green 2

1.16.13 Village Green Project and Use of Sustainable Energy 3

1.8.13 Welcome to the Village Green Project! 20

RECENT POSTS

- > The Village Green Project: Reading the Results So Far...
- > Chequamegon Bay – Day 6: Separating Samples
- > Climate Change and Wildfires: What's the Connection?
- > Life Aboard the Lake Explorer II – Day 4

CATEGORIES

- @EPAREsearch (4)
- Air Quality Awareness (3)

Source Monitoring Applications

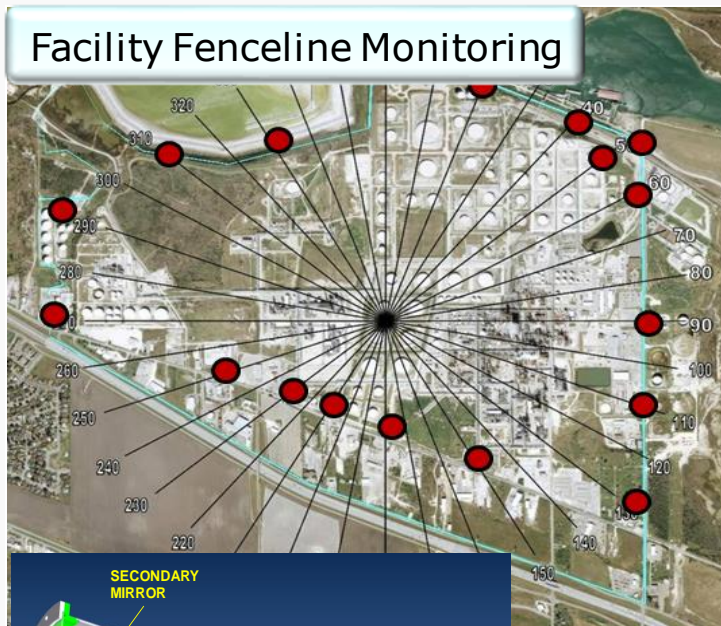


New Opportunities for Source Oriented Monitoring



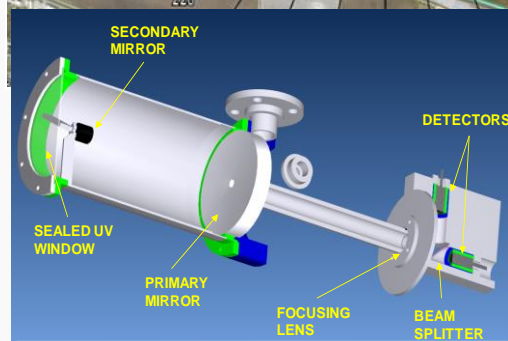
Mid-range Sensors and Remote Measurements

Facility Fenceline Monitoring



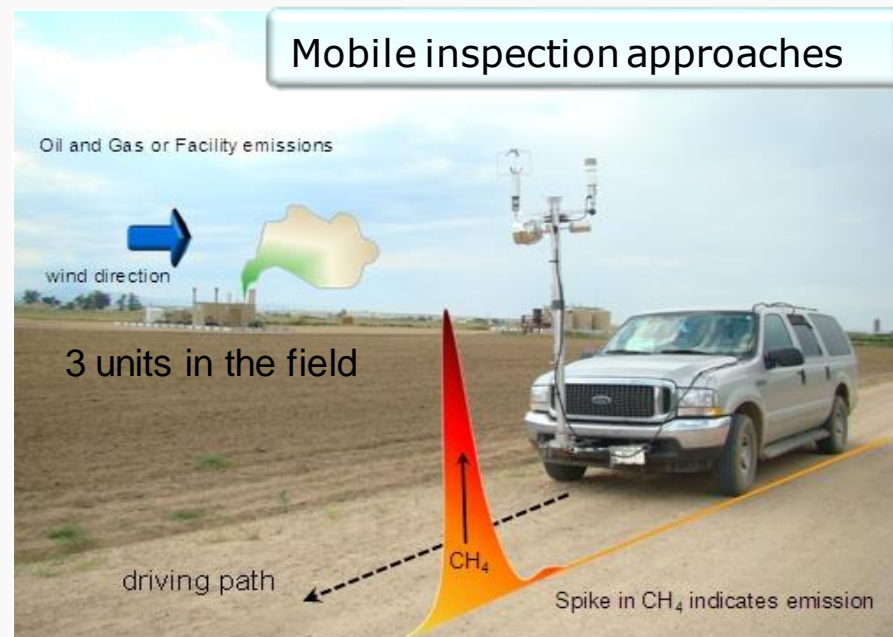
Advanced LDAR and fugitive strategies

- In-plant sensor networks
- IR camera protocols
- Passive samplers



Low cost remote sensing

Mobile inspection approaches



Monitoring Fugitive and Area Sources



Agricultural operations, industrial fugitives, coal mining, waste water, oil and gas production, landfills, and more

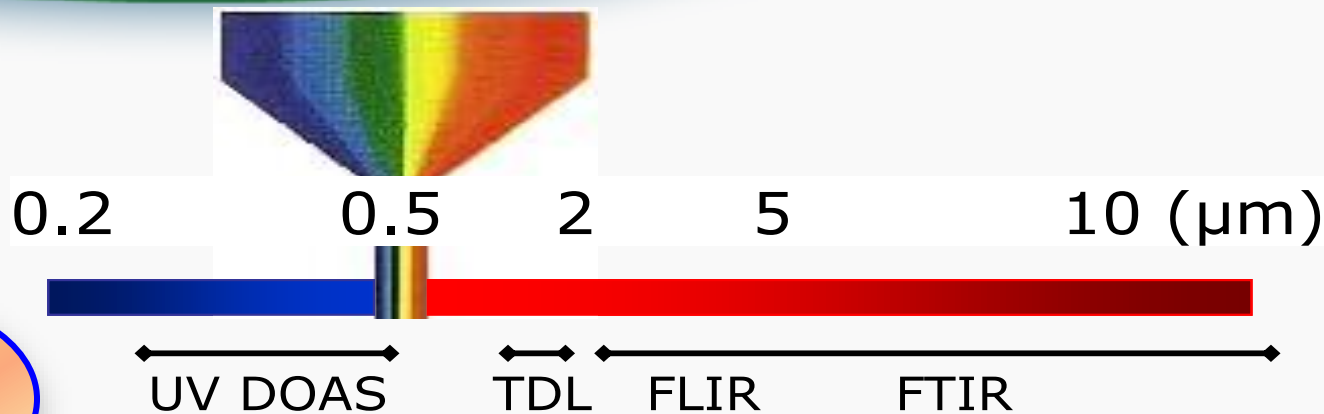
- spatially variable
- temporally variable
- large spatial extent



Source: Microsoft Bing Maps (© Microsoft Corporation Pictometry Bird's Eye © 2010 Pictometry International Corp.)



Open-path Instruments



Open-path
optical
systems



UV Diff. Optical
Absorption
Spectroscopy



Tunable Diode
Laser (scanning)

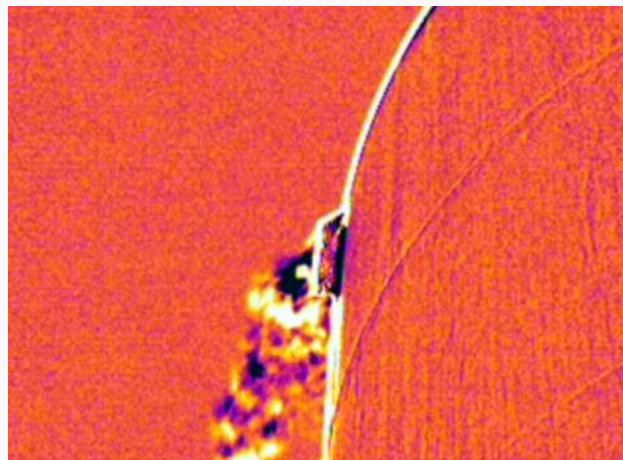
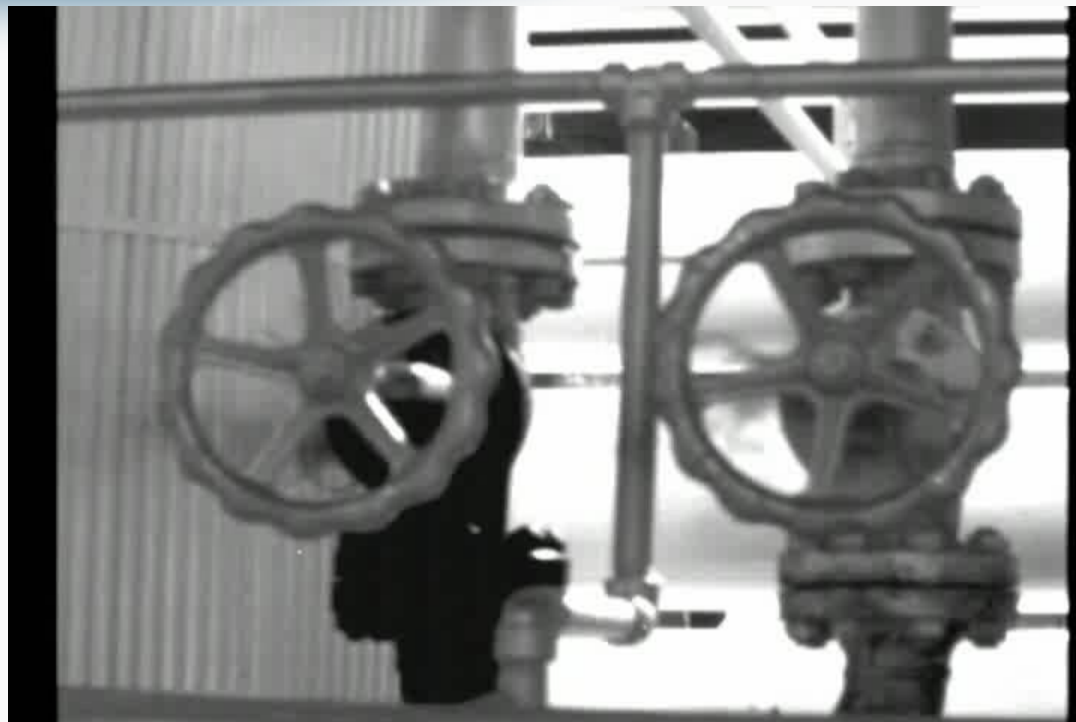


Forward-Looking
InfraRed
(leak imaging)

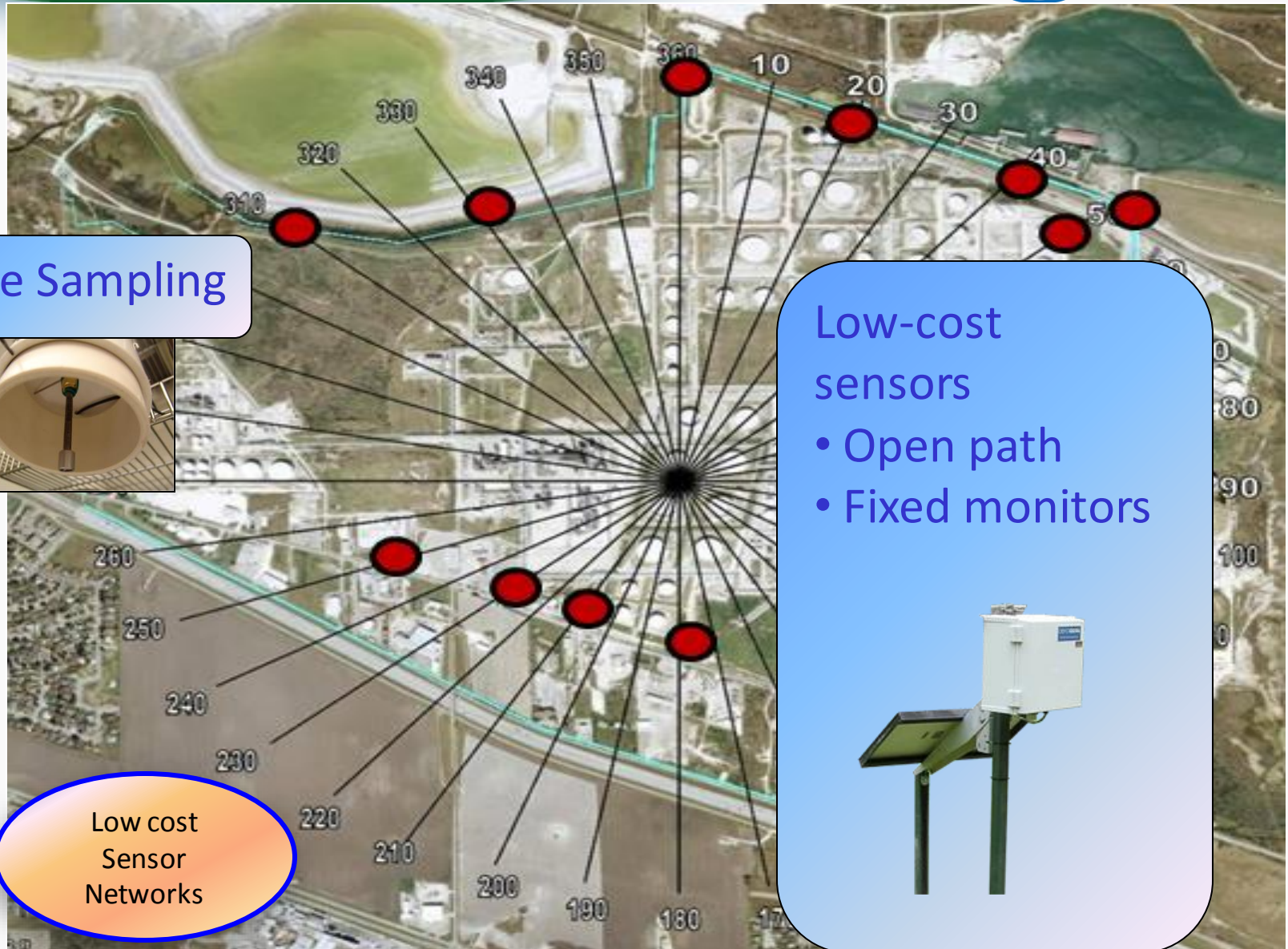


Fourier Transform
InfraRed
(scanning)

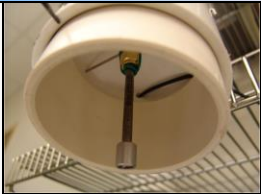
Seeing invisible VOC leaks with infrared video FLIR Camera



Sensor Networks In-plant and Along Facility Fence Line



Passive Sampling




Low-cost sensors

- Open path
- Fixed monitors



Low cost
Sensor
Networks



Open-path fenceline systems to detect emissions and direct quick response leak detection and repair

The image is an aerial photograph of an industrial facility, likely a refinery or chemical plant. A blue line, representing an open-path fenceline system, is drawn around the perimeter of the facility. The line starts at a small square on the left, goes up, then right, then down, and finally right again to another small square on the right. The facility itself contains numerous large white storage tanks, complex piping, and industrial structures. To the left of the facility is a residential neighborhood with many houses. A road runs between the residential area and the facility. A large white cylindrical tank is visible in the upper left. A green plume of smoke or vapor is rising from one of the industrial structures, with a grey arrow pointing to it labeled 'Wind'. In the bottom left corner, there is an orange oval with a blue border containing the text 'Open-path optical systems'.

Open-path
optical systems

Wind

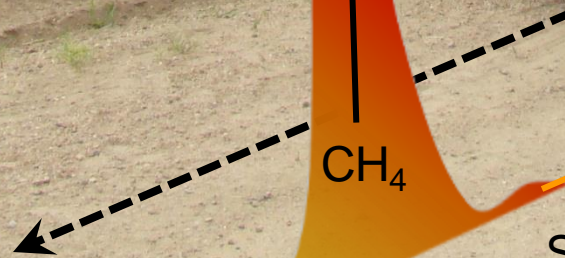
Off-site assessment with *GMAP-REQ*

(Geospatial Measurement of Air Pollution – Remote Emissions Quantification)

wind direction



driving path



Mobile
Inspection
systems

Spike in CH_4 indicates emission



Evaluating Lower Cost Sensor Technology and Regulatory Considerations



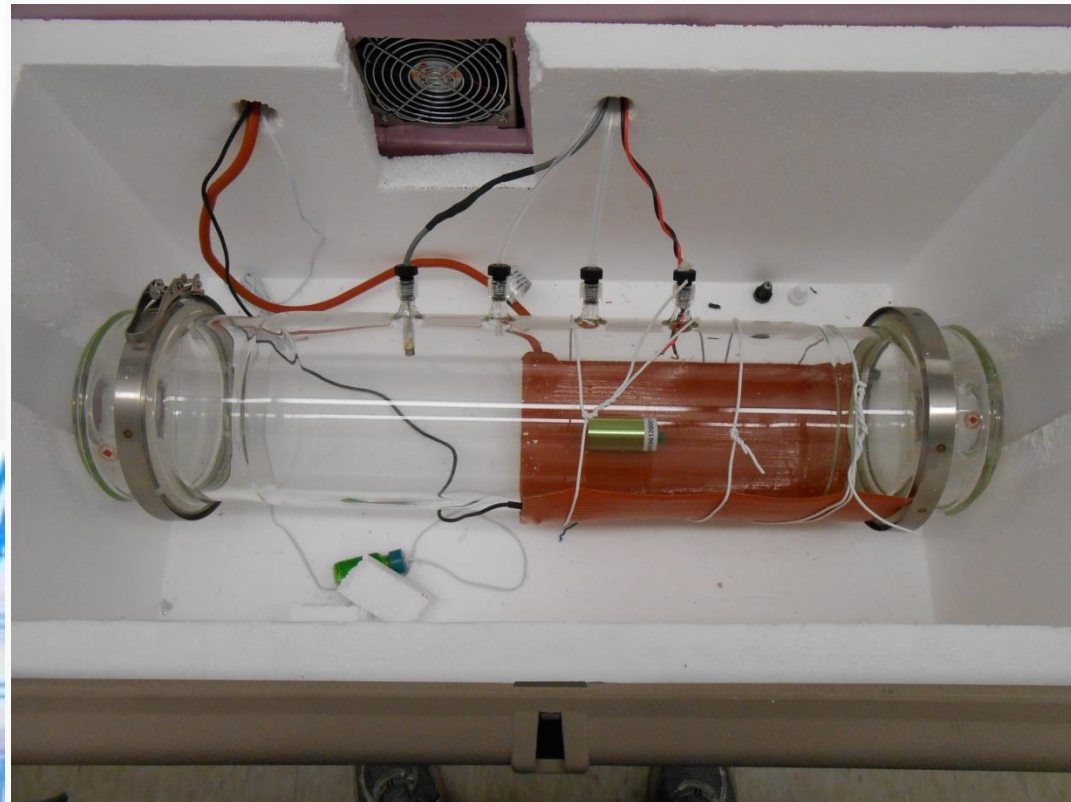
- Under EPA's Air Sensors Evaluation Project the following are being determined for lower-cost O₃ and NO₂ sensors:
 - Linearity (range)
 - Precision of measurements
 - Lower detectable limit
 - Resolution (noise)
 - Response time (lag and rise time)
 - RH and temperature influence
 - Interference equivalent



CairClip electrochemical sensor evaluated under the Air Sensors Project

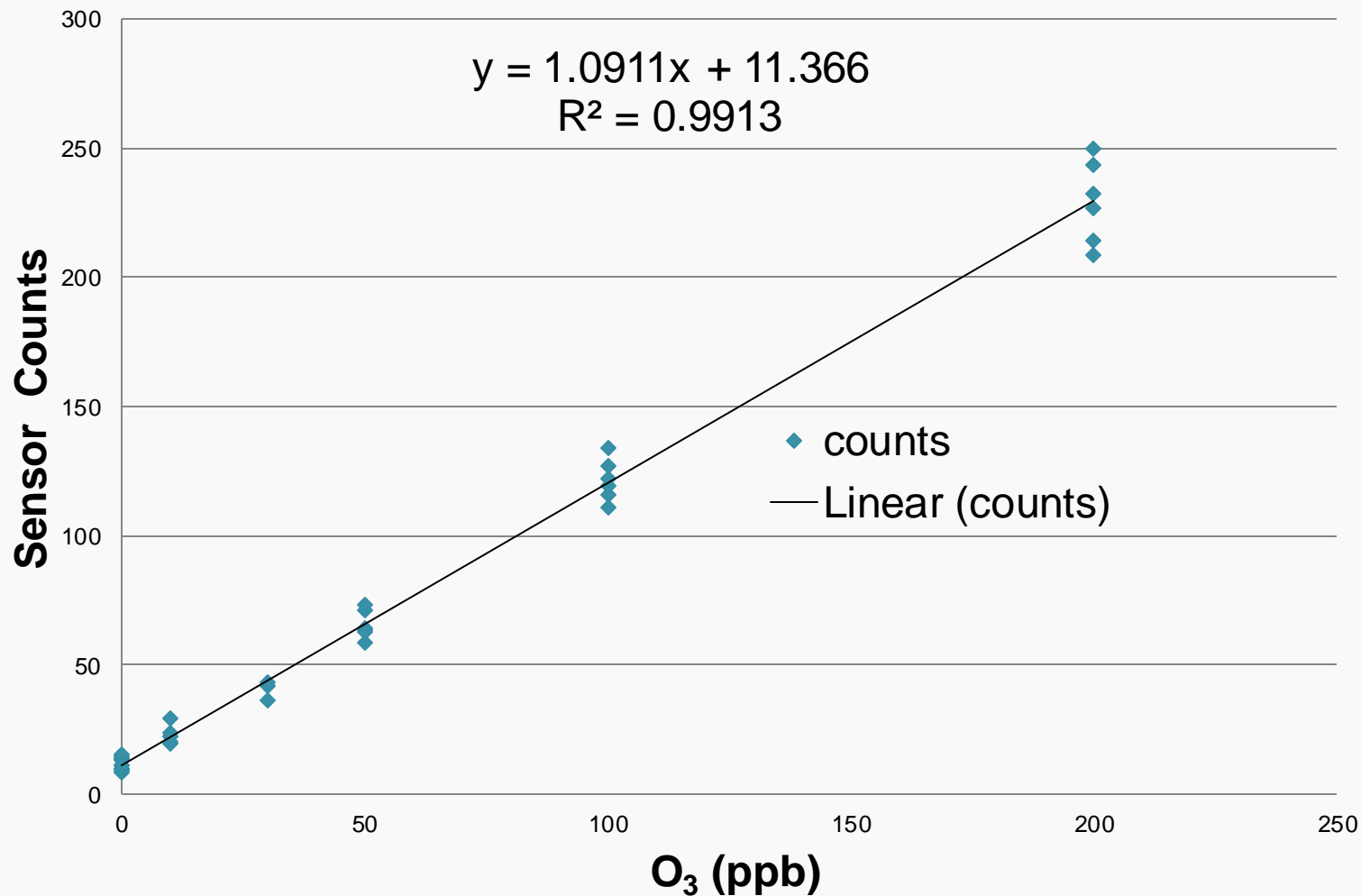
-Findings for ozone and NO₂ will be released late summer.

Evaluating Personal Sensors



CairClip electrochemical
sensor evaluated under the
Air Sensors Project

Cairclip performance against reference analyzer



New Sensor Research in EPA ORD



- A host of low cost (<\$2500) PM_{2.5} and VOC sensors purchased or acquired for laboratory and/or field evaluation by EPA- ORD
- PM Sensors include: RTI μ PEM, Dylos, Met One 831, Carnegie-Mellon Speck, Carpol PM; AirBase; EcoPM
- VOC Sensors include: AirBase; Sensaris EcoSense; Cairpol VOC, Unitec, APPCD, Sensotran, ToxRAE
- Research involves collaborations with NRMRL (Triple Oaks site) and OAQPS (AIRS) to leverage reference monitor collocation. Field work still being completed for VOC.



Sensor Evaluation in Collaboration with NASA (Houston, TX Sept 2013)



- EPA deploying sensor technology (CairClip) for NO₂ and O₃ that performed well during the EPA Sensor Evaluation Open House.
- NASA deploying sensor technology (Geotech AQMesh-5) to measure O₃, NO, NO₂, CO, SO₂.
- Sampling with sensors will be used to evaluate air craft and remote measurements as well as air quality models.
- Provides EPA with additional insights and experience with the use of sensor technologies in the field for future applications.



CairClip



Ongoing and Future EPA Sensor Evaluation Activities



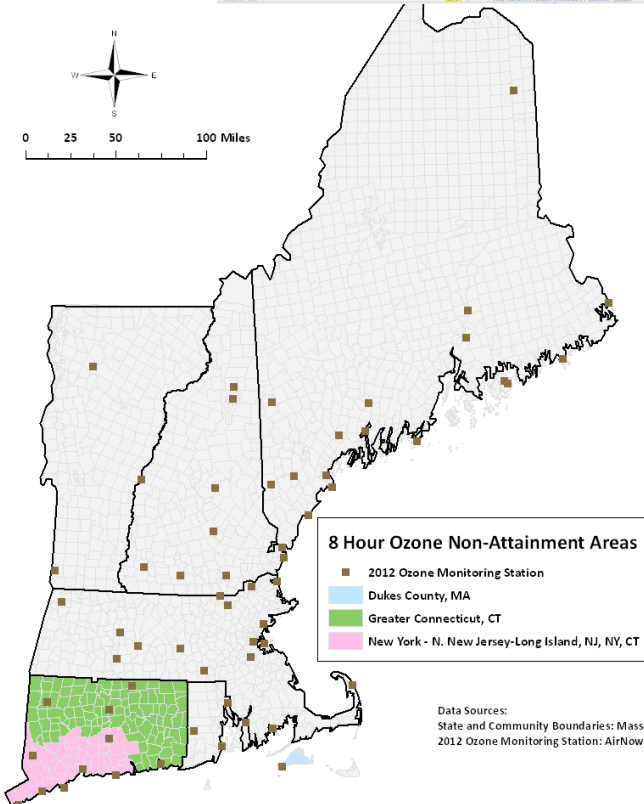
- Results for ozone and NO₂ sensors will be released late summer.
- PM and VOC Sensor Evaluations
 - A host of low cost (<\$2500) PM_{2.5} and VOC sensors purchased or acquired for laboratory and/or field evaluation
 - Field work to be completed soon.
 - Results available fall, 2014
- Advanced sensor related project in EPA Region 4 comparing some of these lower cost sensors to NCore (FRM/ FEM) site



EPA Regional Use of Air Monitoring Data

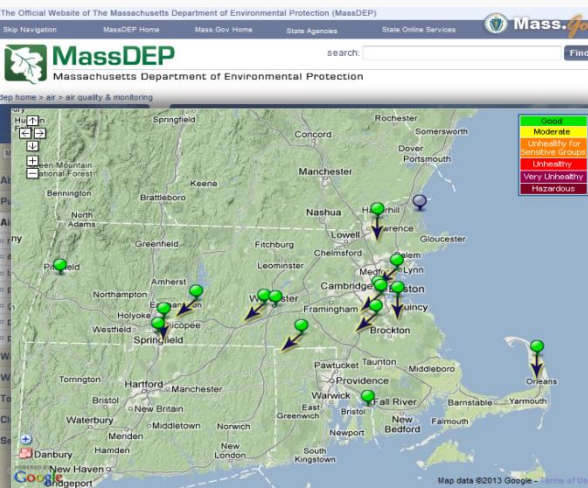


- Real time data reporting to AQI/ AIRNow and State web sites.
- Determine areas which meet the NAAQS.
- For nonattainment areas, State/ locals must develop pollution control strategies to reduce emissions.
- Support health studies...



Data Sources:
State and Community Boundaries: MassGIS
2012 Ozone Monitoring Station: AirNow

Map Produced by U.S. EPA Region 1
May 1, 2012



U.S. Environmental
Protection Agency

So why not use the “egg”?

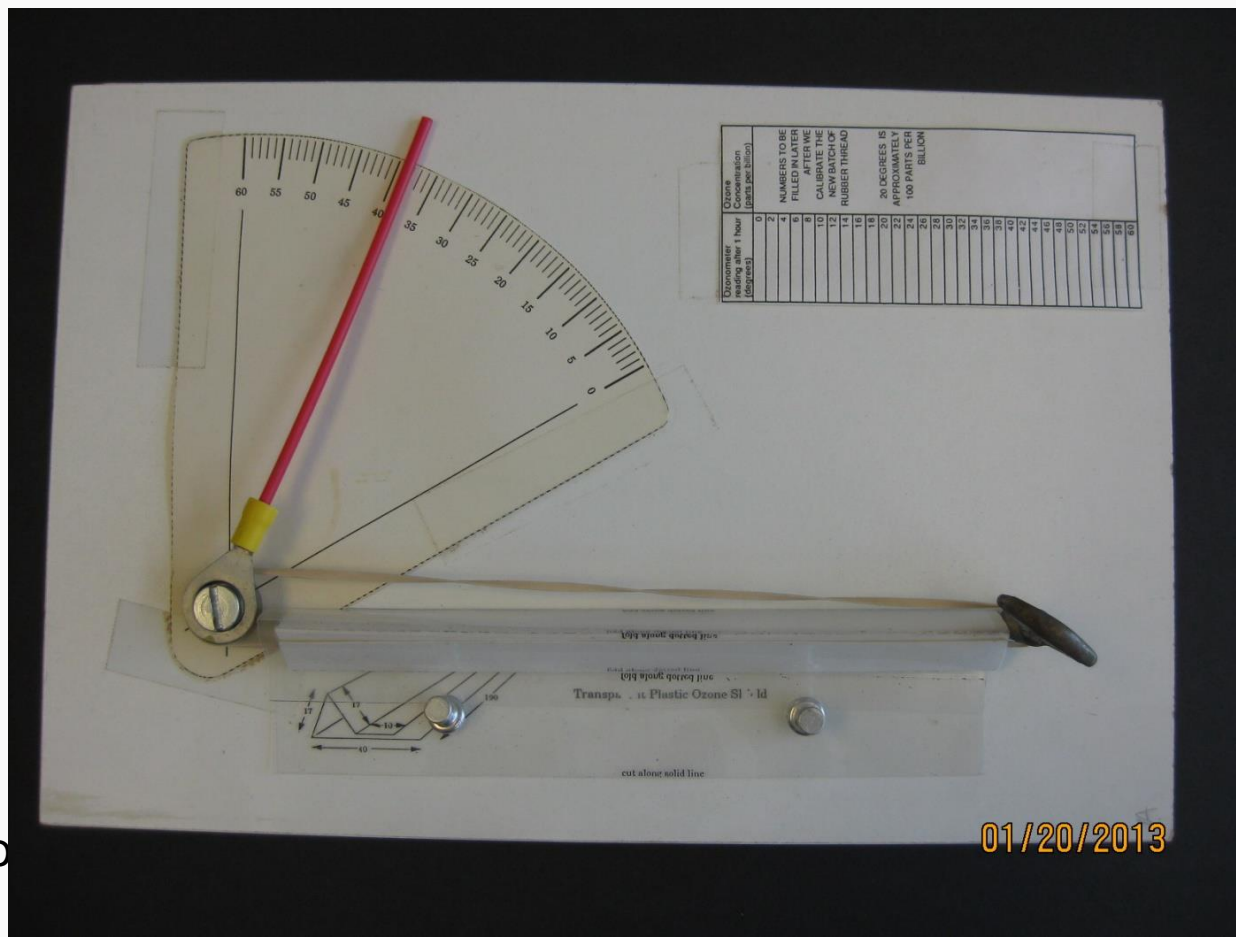
- Could we use a simpler, less expensive device than we currently use to measure pollutants to make decisions?



“The Air Quality Egg is a sensor system designed to allow anyone to collect very high resolution readings of NO₂ and CO concentrations outside of their home. These two gases are the most indicative elements related to urban air pollution that are sense-able by inexpensive, DIY sensors”– Air Quality Egg Website

The concept of cheaper, simplified air quality measurements is not “new”

- Depicted is a 1940's vintage ozone monitor-with its “detector” - a rubber band...



So why did we develop *more complicated* measurement devices?

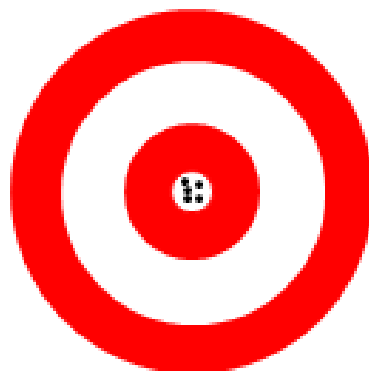


- Quality Assurance/
Quality Control
- DQOs (data quality objectives)
- Data completeness, precision, bias and overall accuracy
- Audits

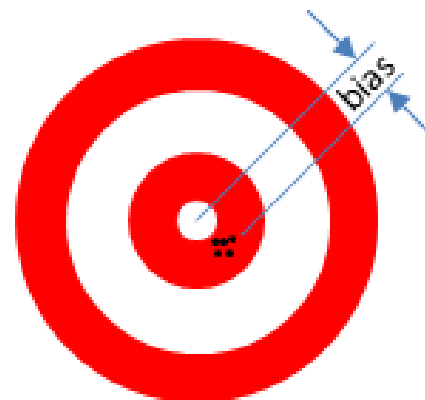
3/20/2014



We need unbiased **and** precise measurements...



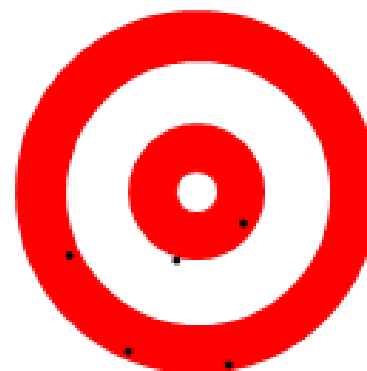
unbiased, precise



biased, precise



unbiased, imprecise



biased, imprecise



This is where we'd like to be....*accurate!*

- EPA established FRMs and FEMs to ensure consistency...



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EXPOSURE RESEARCH LABORATORY
HUMAN EXPOSURE & ATMOSPHERIC SCIENCES DIVISION (MD-D205-03)
Research Triangle Park, NC 27711

Office of
Research and Development

LIST OF DESIGNATED REFERENCE AND EQUIVALENT METHODS

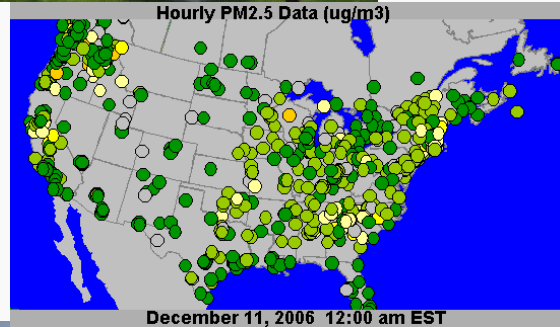
Issue Date: December 17, 2012
(www.epa.gov/ttn/amtic/criteria.html)

These methods for measuring ambient concentrations of specified air pollutants have been designated as "reference methods" or "equivalent methods" in accordance with Title 40, Part 53 of the Code of Federal Regulations (40 CFR Part 53). Subject to any limitations (e.g., operating range or temperature range) specified in the applicable designation, each method is acceptable for use in state or local air quality surveillance systems under 40 CFR Part 58 unless the applicable designation is subsequently canceled. Automated methods for pollutants other than PM₁₀ are acceptable for use only at shelter temperatures between 20°C and 30°C and line voltages between 105 and 125 volts unless wider limits are specified in the method description.

Prospective users of the methods listed should note (1) that each method must be used in strict accordance with its associated operation or instruction manual and with applicable quality assurance procedures, and (2) that modification of a method by its vendor or user may cause the pertinent designation to be inapplicable to the method as modified. (See Section 2.8 of Appendix C, 40 CFR Part 58 for approval of modifications to any of these methods by users.)

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Protection Agency

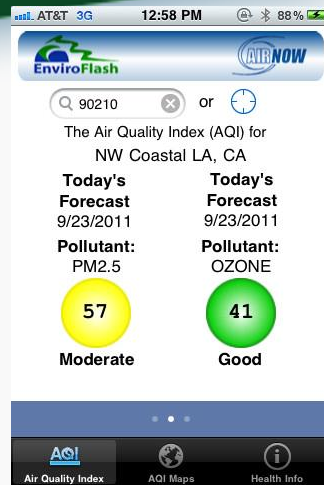
Bridgeport, CT



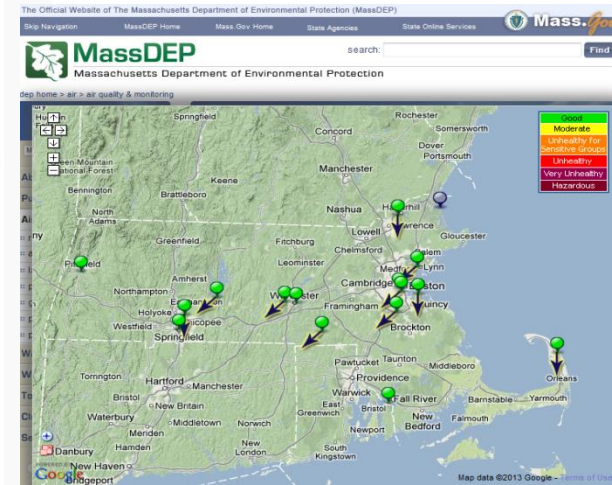
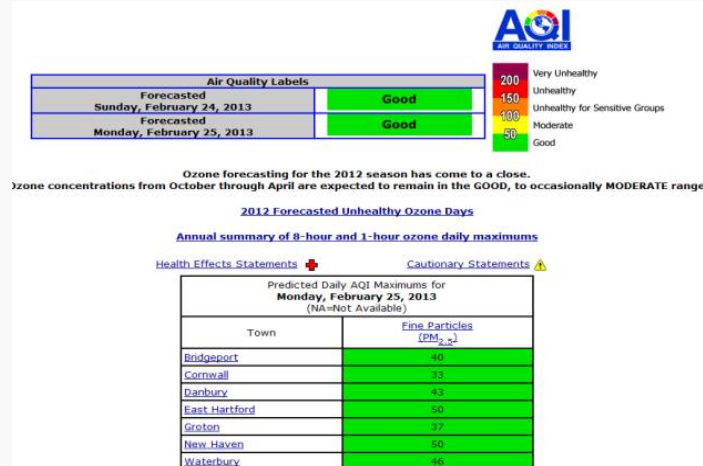
Narragansett, RI

Monitoring in New England

**How does
your monitor
compare to
other
measurements?**



McFarland Hill, Acadia NP Bar Harbor, ME





What can be done to make these low cost monitors useful to the regulatory community?

- EPA- ORD “evaluation” of reliability of measurement. Is it...
 - FEM/ FRM quality? http://www.twobtech.com/model_202.htm
 - Very good, but not FEM?
 - Adequate for “personal exposure” assessment (+/- 30%, or better/lower?)?
 - “Junk”?
- How prone is it to operator error, especially with multiple operators?
- Operation and maintenance (SOPs)
- Instrument calibration needs
- QA/ QC issues and questions- what type of quality procedures do you need to have in place?





How can data* from these low cost monitors be useful to the regulatory community?

- A screening tool, to identify a problem area/ “hot spots”
- Personal exposure, health risks
- General environmental awareness
- Emergency planning for air toxics/ superfund
- Helping S/L with siting new monitors?


***Monitor must be operated consistent within its limitations, and in accordance with its operating manual.**



EPA Next Generation Air Monitoring Site



For More Information:

 **EPA** United States Environmental Protection Agency

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Next Generation Air Monitoring

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Next Generation Air Monitoring

Background

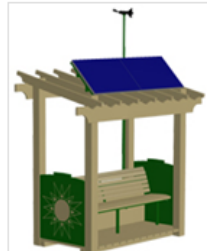
Traditionally, air pollution is measured by expensive, stationary and complex air-monitoring instrumentation. Only a few organizations, like Federal, State and some industries, typically collect data of such high quality. Even so, this limits the amount of environmental monitoring data that is often available for exposure and health assessments. As air quality management problems become more complex, there is a need for enhanced air quality and exposure monitoring capabilities.



To meet this growing technological need, EPA, the commercial sensor industry, academic institutions, and others, are developing, evaluating and applying a variety of innovative technologies. Currently, EPA is investigating the means to monitor personal air quality in community settings, and other areas of interest.

These air sensors range anywhere from an application on a cell phone to a device that gives by-the-minute, real-time data while interacting with the public, like the [Village Green Project](#).

This project developed a solar-powered air monitoring system in the shape of a bench, and encourages the public to interact and learn more about their local air quality. People can interact with the bench system with their Smartphones and see current local air quality and meteorological conditions. The air pollutants being measured include ozone, black carbon and particulate matter where the system automatically sends collected data to an online, open-sourced website. This system is charged by two solar panels and will automatically turn off in dark, cloudy conditions and re-start once the sun again comes out.



Related Links

- [Background](#)
- [Air Sensor Studies](#)
- [Moving Forward with Collaboration](#)

Resources

- [Roadmap for Next Generation Air Monitoring](#)
- [Air Sensor Evaluation and Collaboration](#)
- [My Air, My Health](#)
- [EPA Exposure Research](#)
- [Village Green Project Blogs](#)
- [Air Sensor Blogs](#)
- [March 2013: Air Sensors 2013: Data Quality and Applications](#)
- [Next Generation Air Monitoring presentation \(PDF\) \(21 pp, 2.8MB\)](#)

Acknowledgements



EPA Office of Research and Development: Ron Williams, Russell Long, Emily Snyder, Eben Thoma, Bill Mitchell, Brian Gullett, Stacey Katz, Gail Robarge, Rachel Duvall, Tim Watkins

EPA Office of Air Quality Planning and Standards: David Shelow



Questions?

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